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Economic Evaluation of Occupational Safety and Health Interventions From the Employer Perspective

A Systematic Review

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Objectives: The aim of this systematic review was to evaluate the cost-effectiveness of occupational safety and health interventions from the employer perspective. **Methods:** A comprehensive literature search (2005 to 2016) in five electronic databases was conducted. Pre-2005 studies were identified from the reference lists of previous studies and systematic reviews, which have similar objective to those of this search. **Results:** A total of 19 randomized controlled trials and quasi-experimental studies were included, targeting diverse health problems in a number of settings. Few studies included organizational-level interventions. When viewed in relation to the methodological quality and the sufficiency of economic evidence, five of 11 cost-effective occupational safety and health (OSH) interventions appear to be promising. **Conclusion:** The present systematic review highlights the need for high-quality economic evidence to evaluate the cost-effectiveness of OSH interventions, especially at organizational-level, in all areas of worker health.

Learning Objectives

- Discuss the need for research on the cost-effectiveness and cost benefits of occupational safety and health (OSH) interventions, along with the limitations of previous studies.
- Summarize the findings of the present review of economic evaluations of OSH interventions from the employer's perspective, including the characteristics of the cost-effective interventions identified.
- Discuss the implications for future efforts to analyze the financial benefits of OSH interventions.

There is a growing interest in the economic value of occupational safety and health interventions mainly because of the limited resources allocated for occupational safety and health (OSH) interventions and the knowledge that proven economic gains are attractive to employers. Recent survey data from 500 organizations found that 73% of employers believe health and safety requirements benefit their business as a whole, while 64% reported they save money in the long term. As safety initiatives may be efficient but may not always bring a financial return to an organization, information about the economics of OSH interventions is important and an invaluable input for decision making.[1–3] Health economic evaluation seeks to explicitly identify, measure, and value all relevant cost and benefit parameters and aims to inform all decision-makers of the circumstances where indirect costs exceed direct costs and the relative costs and benefits (cost-effectiveness) of the different intervention options available.[4]

The costs of occupational injuries and illnesses together with the demonstrated cost-effectiveness of OSH interventions constitute an important incentive for employers to adopt these interventions.[5] They are especially interested in whether investment in a program is cost-effective (the effects give good value for the money invested) or cost beneficial (the financial benefits are favorable).[6] A previously published systematic review evaluating the economics of OSH concluded that most published intervention studies so far focused on interventions' effectiveness rather than on their cost-effectiveness. It also concluded that further high-quality studies conducting full economic evaluations are needed in order to be able to draw further conclusions about the cost-effectiveness of OSH interventions from an employer's perspective.[7]

Because of the above-mentioned problems, our knowledge on the cost-effectiveness of OSH interventions remains unsatisfactory. In order to fill the gaps and shortcomings previously identified in the literature, the aim of the present review was to evaluate the cost-effectiveness of primary and secondary OSH interventions from the perspective of the employer. Primary preventive interventions are proactive and aim to prevent the occurrence of illness among healthy individuals, while secondary interventions are ameliorative and aim to reduce prevalence by early detection. Thus, both primary and secondary OSH interventions can contribute to overall disability prevention or control before the disability becomes chronic or severe. Tertiary preventive interventions, as reactive

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AG (Aikaterini Grimani) was the leader author and contributed to the study design, screening process (as a reviewer), eligibility process (as a reviewer), data extraction, methodological quality evaluation. GB (Gunnar Bergström) contributed, as a senior expert, to the study design, methodological quality assessment procedure, revised the paper critically, and contributed to it intellectually. MRC (Martha Isabel Riaño Casallas) contributed to the study design, eligibility process (as a reviewer), data extraction, and was involved in the writing process. EA (Emmanuel Aboagye) contributed to the study design and methodological quality evaluation. IJ (Irene Jensen) contributed, as a senior expert, to the study design, revised the paper critically, and contributed to it intellectually. MLK (Malin Lohela Karlsson) was the study supervisor and contributed to the screening process (as a reviewer), the eligibility process, data extraction, methodological quality evaluation (as a consultant reviewer), revised the paper critically, and contributed to it intellectually. All the authors have read and approved the final version of the manuscript.

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strategies, were not part of our aim.[8–10] Furthermore, this review only looked at interventions that attempted to reduce exposure to deleterious aspects of the workplace.[11] According to Alli,[12] *OSH is generally defined as the science of the anticipation, evaluation, recognition and control of hazards arising in or from the workplace,* achieving a strong preventive safety culture (pp. vii). Worksite Health Promotion interventions that attempted to change the individual behavior related to health problems that did not arise in or from the workplace, promoting healthy behaviors such as weight control, healthy nutrition, smoking cessation, influenza vaccination, were excluded.[6,11,13]

The systematic review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[14,15] and the Assessment of Multiple Systematic Reviews (AMSTAR) guidelines.[16] The protocol was registered with PROSPERO (registration no: CRD42016046897).

METHODS

Inclusion Criteria and Search Strategy

A systematic review of economic evaluations of OSH interventions from the employer perspective was conducted. A search strategy following PICOS was developed. The PICOS process is a method for putting together a search strategy that facilitates a more evidence-based approach to literature searching. PICOS is an acronym that stands for population, intervention, comparison, outcome, and study design. It orients the construction of the literature search and helps to rapidly and accurately locate the best available scientific information and avoid unnecessary searching.[17]

Two experienced search specialists from the university library developed the search strategy (see Table C, http://links.lww.com/JOM/A394) based on PICOS and some relevant published papers known to the project group. The search strategy included working population, primary and secondary OSH interventions, all types of control groups, economic consequences and health outcomes, randomized controlled trials (RCTs), and quasi-experimental study designs. Schelvis, et al[18] highly recommend researchers conducting systematic reviews to broaden their inclusion criteria and not neglect evidence from studies which apply alternative research designs, thereby improving the quality of reporting non-RCTs. We therefore decided to include all study designs with a predefined control group.

The search was conducted in five electronic databases: Medline (OVID), EMBASE.com, Web of Science Core Collection, Cochrane Library (Wiley), and PubMed (not Medline) and covered the period 2005 to April 2016. The studies conducted before 2005 have been included in previous studies and systematic reviews with similar aims as the present search with regard to the economic evaluation of workplace interventions (see for instance).[2,6–8,19–21] These studies were thus identified from the reference lists and included if they fulfilled our inclusion criteria. Additional databases were also searched. Supplemental searches were conducted in the National Institute for Occupational Safety and Health database (NIOSH), the NHS Economic Evaluation database (NHS EED), and in the Google scholar search engine, using the same search words as in the other databases. The search was carried out in accordance with the process recommended by the Cochrane Collaboration.[22]

Selection Strategy

The screening of abstracts and titles was conducted by four reviewers (EC, CS, MLK, AG). The abstracts were included if at least one of the following criteria was met: the title/abstract implied or referred to a workplace setting; the title/abstract referred to an OSH intervention study; the title/ abstract referred to a full economic evaluation study. Two reviewers (AG, MRC) then independently determined the eligibility of studies on the basis of a review of the full texts, using a predesigned criteria form (see Table A; Supplementary Material file, http://links.lww.com/JOM/A394). Differences between them were resolved through a consensus procedure or, if the disagreements persisted, a third reviewer was consulted (MLK). Studies were selected on the basis of the following criteria: 1) the study was a primary or a secondary OSH intervention; 2) the study included a full economic evaluation; and 3) the economic analysis of the intervention was conducted from an employer/company perspective. Only studies written in English were included. In addition, only studies where the described intervention was undertaken in a Western developed country were included—based on the assumption that the OSH context varies between developed and developing countries.[7] Studies that constitute ''grey literature,'' editorials, letters, reviews, and articles describing either a partial economic evaluation or the design of an economic evaluation or an economic evaluation tool without any reported results were excluded.

Data Extraction and Evidence Synthesis

To guide the data extraction procedure, the key elements of existing guidelines and relevant systematic reviews as well as texts about economic evaluation were identified (see for instance).[2,7,19,20,22] A data extraction form was developed, reviewed, and refined by the researchers to better capture the key factors that were essential for evaluation, synthesis, and presentation, thus ensuring the adequacy of the tool. The data extraction form included location, occupation/the industrial sector of the target population, number of participants, company size and type, health category and target problem, type of study design, total study duration, type and description of the intervention, type of economic evaluation and description of economic analysis, main economic evaluation results, costs, economic consequences, other outcomes, and a description of these. One reviewer extracted the data (AG), while a second reviewer (MLK) checked all the extracted data. Any discrepancies were resolved through a consensus procedure. It was not possible to conduct a meta-analysis due to the heterogeneity of study designs, populations, interventions, and outcomes. Because of the diversity of the studies' components, we chose to stratify them according to health problems.

Quality Assessment

In order to evaluate the methodological quality of the studies included in the review, two quality assessment tools were used. After a thorough search, the Cochrane Collaboration Risk of Bias (CCRBT)[22,23] and the Consensus on Health Economic Criteria (CHEC-list)[24] were chosen. The Cochrane Collaboration strongly encourages all reviewers to use the CCRBT to establish consistency and avoid discrepancies in the assessment of methodological quality among all review groups. It also encourages reviewers to use the CHEC-list for critical appraisal of the methodological quality of health economic evaluation studies.[25]

CCRBT is a two-part tool, addressing seven evidence-based domains, namely random sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective outcome reporting (reporting bias), and other sources of bias (other bias). The first part of the tool gives sufficiently detailed support for judging the risk of bias, ensuring its transparency. The second part assigns a judgment relating to the risk of bias for each domain. This is achieved by assigning a judgment of ''Low risk'' of bias (+), ''High risk'' of bias (-), or ''Unclear risk'' of bias (?). In line with the Cochrane Collaboration's recommendations, those studies in which all the domains were rated positively were judged as having a low

risk of bias, while the studies with one or more unclear domains were judged as having an unclear risk of bias. Furthermore, studies with one or more negatively rated domains were judged as having a high risk of bias.[22,25] In our review, the first two domains (random sequence generation and allocation concealment) were marked as not applicable for the quasi-experimental study designs. Although the tool was not developed with nonrandomized studies in mind, the general structure of the tool and the assessments seems useful to follow when creating risk of bias assessments for quasi-experimental studies.[22]

The CHEC-list consists of 19 yes (1) or no (0) questions, which address internal and external validity aspects of economic evaluation studies (19, or 100%, was the highest score). In accordance with the summary assessment of Uegaki et al,[20] the studies that met less than 50% of criteria were seen as having low methodological quality of undertaking and reporting economic evaluations, while the studies that met more than 75% of criteria were seen as having a high methodological quality of undertaking and reporting economic evaluations. The studies that met between 50% and 75% of criteria were considered to have a moderate methodological quality of undertaking and reporting economic evaluations. Five of the internal quality criteria relate to study design; 11 internal criteria relate to the conduct of the economic evaluation, while the last two internal criteria address the issue of incremental analysis of costs and outcomes and sensitivity analysis. Finally, one external criterion relates to the discussion of the generalizability of the obtained results.[20,24]

Two review authors (AG, EA) independently evaluated the methodological quality of each study using both assessment tools. Discrepancies were resolved by means of a consensus procedure. If the disagreements persisted, the reviewers consulted a third reviewer (MLK). A senior expert (GB) contributed to the assessment procedure whenever it was deemed to be necessary.

RESULTS

Literature Searches

Our primary search in the predefined databases resulted in 4096 hits. A further 899 hits were found in other sources, giving a total of 4995 citations (see Fig. 1). The latter included references from relevant studies and systematic reviews, publications from the NIOSH, the NHS EED, and Google scholar. After duplicates were removed ($n = 1415$), a total of 3580 citations were screened. Of these, 3342 citations were excluded on the basis of title, keywords, and abstract. The full text of the remaining articles ($n = 238$) was then assessed, resulting in 19 articles being retained. The reasons for exclusion are presented in Fig. 1.

Description and Characteristics of Included studies

Working populations from the following sectors were represented: health care, retail and trade, construction, manufacturing and warehousing, transportation, communication, business, and professional services. Half of the studies (10 of 19) were undertaken in Europe. Six studies were carried out in the United States and one each in Canada, North America, and Australia. Sample sizes ranged from 50 to 3047 employees (10,026 in total; mean sample size: 528; median sample size: 262). The studies reported on a range of

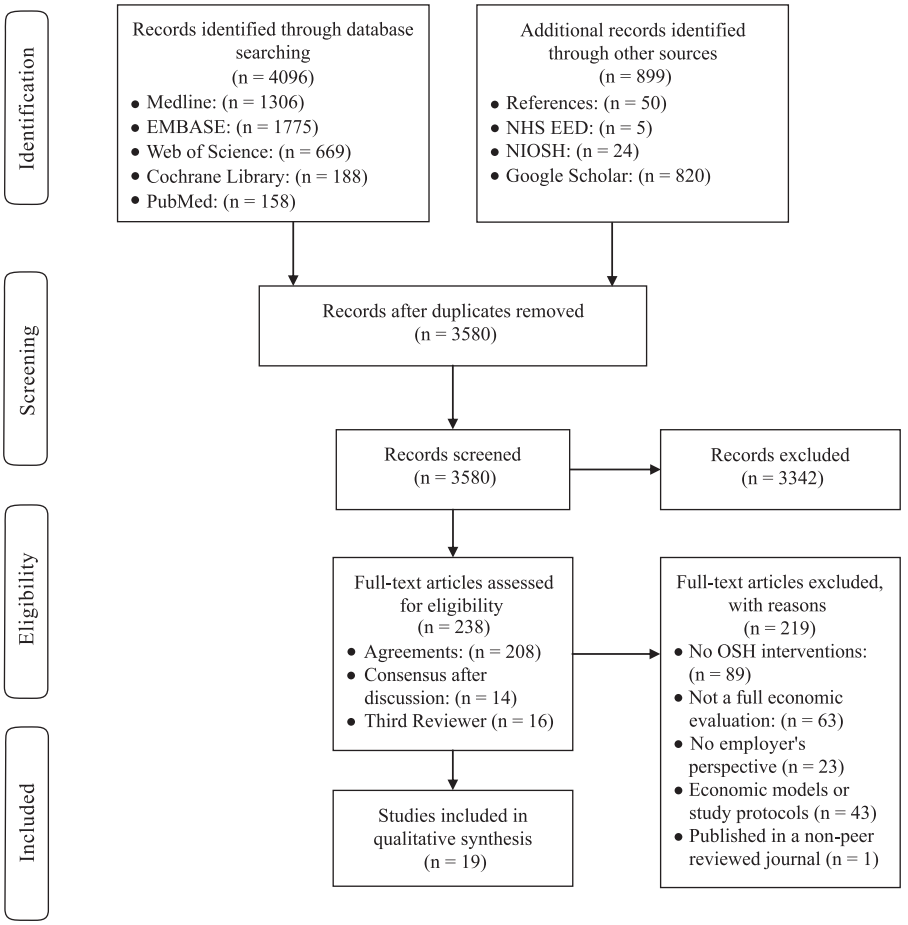

FIGURE 1. Flow chart.

intervention types, such as training, education, naturopathic care, visits to practitioners and therapists, as well as safety equipment (for instance back belts, safety cutters, ceiling lifts, protective devices). The studies addressed either individual-level ($n = 14$) or organizational-level interventions ($n = 4$), or both ($n = 1$). The follow-up period ranged from 6 months to 6 years, with 12 months as the most common duration for most studies ($n = 12$). In 15 studies, the design was a RCT. Three studies had a controlled before-after design, while one used a case–control design. Eight studies were conducted in the 1990s, while only two studies were conducted during the following decade. The remaining half of the included studies were published between 2010 and the beginning of 2016. The intervention studies included in the review covered a broad range of interventions targeting different types of health outcomes. Some interventions focused on primary prevention, others on secondary prevention, and some on both. The studies were stratified according to the targeted health problems. Three categories were compiled: musculoskeletal disorders (MSDs) ($n = 10$), mental health ($n = 3$), and other preventive interventions ($n = 6$).

Table 1 includes an overall description of the interventions and details of the study designs. The largest group of economic evaluations of OSH interventions was conducted on MSDs, such as low back pain ($n = 5$), back injuries ($n = 3$), and neck and upper limb symptoms ($n = 2$).[26–35] The participants were workers with a high prevalence of MSDs from large, diverse industries, such as bus drivers, county government workers, postal workers, computer workers, warehouse workers, and coal miners. Half of the studies were conducted in the 1990s. Eight were individual-level RCT interventions and one was a multilevel intervention.[28] Only one study was an organizational-level case–control study intervention.[31]

Three studies evaluated the cost-effectiveness of interventions targeting mental health problems such as depressive symptoms, mental health complaints, and work-related stress.[36–38] Two of the studies were carried out in 2015 and were RCTs, while the older study was a controlled before-and-after design. All studies were individual-level interventions. The participants were from banking companies, research institutes, security companies and universities, or were health care workers.

In the group of other preventive interventions, the studies focused on other health categories, particularly injuries,[39–41] health and work ability,[42] hand eczema,[43] and substance abuse.[44] Four such studies were conducted over the last 15 years. Four of these were RCTs, while the remaining two studies were controlled before-and-after design. Most of the studies ($n = 3$) dealt with organizational-level interventions. The participants were from large diverse industries, such as the healthcare, construction, local authority council, retail, and trade.

The main characteristics of the economic evaluations carried out in each of the studies are presented in Table 2.

Quality Assessment

The overview of risk of bias assessment is summarized in Table 3. Overall, the intervention studies were judged as having an unclear risk of bias, as the majority of them were rated as having either low or unclear risk of bias (see Cochrane Collaboration's recommendations).[22] Older studies (before 2005) had at least one domain judged as having unclear or high risk of bias, while more recent studies were rated as having either low or unclear risk of bias.

The overview of the CHEC-list and the percentage achieved by the studies are presented in Table 4. Older studies generally scored poorly (between 42% and 74%) on the aspects of the assessment due to the insufficient information, while more recent studies achieved better methodological quality scores (between 58% and 95%) related to undertaking and reporting economic evaluations. The most prevalent methodological shortcomings for more than half of the studies were no sensitivity analysis and no discussion of the generalizability of findings. None of the studies discussed ethical issues or elaborated on the characteristics of the intervention population, which indicates possible distributional implications. All studies except two[29,38] conducted an incremental analysis.

Cost-effective Interventions

The review has identified 11 cost-effective OSH interventions based on statistically significant results. Of the MSD interventions, five studies[27,30,32,34,35] reported cost savings or monetary benefits in favor of the following interventions: work style, naturopathic care, back injury prevention program, spinal care lecture, back school program. The cost-effective study with the work style intervention achieved a high score on CHEC-list and had a low risk of bias.[27] The other four cost-effective studies in the group[30,32,34,35] achieved high, moderate, or low scores on the CHEC-list and had either unclear or a high risk of bias (see Table 5). Three of the cost-effective studies conducted a cost-effectiveness analysis (CEA),[27,30,35] while two conducted a cost–benefit analysis (CBA).[32,34] The cost-effective studies reported the difference between monetary benefits and program costs as net savings or benefits, or as the return on investment (ROI). They also identified the direct as well as the indirect costs of the interventions. The main economic consequence was savings due to absenteeism or productivity loss. Other outcomes dealt with the reduction of neck/shoulder pain, (low) back pain, and back injuries.

In the group of mental health interventions, the occupational physician consultation program[37] and the communication skills training program[38] were cost beneficial. The intervention study with the occupational physician consultation program achieved a high score on the CHEC-list and had a low risk of bias,[37] while the other study achieved a moderate score on the CHEC-list and had a high risk of bias[38] (see Table 5). Both studies conducted a CBA and reported the difference between monetary benefits and program costs as net savings or benefits, or ROI. The studies included both direct and indirect costs. The economic consequence of the interventions of both studies was the savings due to absenteeism or productivity loss. A range of outcomes were evaluated, such as mental health complaints, staff turnover, and work-related stress.

In the group of other preventive interventions, two organizational-level interventions (new safety cutters with education[39] and ceiling lifts),[40] which conducted a CBA, one individual-level intervention (physical therapist training session),[42] which conducted both a CEA and a CBA, and one individual-level intervention (alcohol brief consultation),[44] which conducted a CUA, reported cost savings or monetary benefits. The individual-level intervention study of Hengel et al[42] achieved a high score on the CHEC-list and had a low risk of bias, while the other individual-level intervention study achieved a moderate score on the CHEC-list and had a low risk of bias.[44] The two organizational-level intervention studies had moderate scores on CHEC-list and unclear risk of bias[39,40] (see Table 5). The studies reported the difference between monetary benefits and program costs as net savings or benefits. Most of the studies took both the direct and the indirect costs of the interventions into account. The predominant economic consequences were productivity losses, the wage value of working time loss due to injury, and workers' compensation expenses.

Interventions not Shown to be Cost-effective

Eight OSH interventions not shown to be cost-effective were identified. In the group of MSD interventions, five studies[26,28,29,31,33] were not shown to be cost-effective. Driessen et al[28] achieved a high score on the CHEC-list and had a low risk of bias. The other four studies in the group achieved either high[26,33] or low[29,31] scores on the CHEC-list and had an unclear risk of bias.

TABLE 1. Data Extraction Presented for Targeted Health Problems: Study Design Characteristics and Intervention Description

		Country; Industrial Sector; Company size	Number of Participants; Target Problem	Type of Study Design; Measurement Time Period	Type and Description of the Intervention
Musculoskeletal disorders	Aboagye et al [26]	Stockholm, Sweden	159 workers; low back pain	RCT; 12 months	Individual (training therapies and advice); Group A: medical yoga ($n = 52$), Group B: exercise therapy ($n = 52$), Group C: self-care advice group ($n = 55$).
	Bernaards et al[27*]	Netherlands; 6 companies	466 computer workers; neck and upper limb symptoms	RCT; 12 months	Individual (work style and physical activity); Group A (WS): work style intervention ($n = 152$; 60 min/meeting), Group B (WSPA): work style and physical activity intervention ($n = 156$; 90 min/ meeting), Group C: usual care ($n = 158$; receive breaks and exercise reminder software like the other groups).
	Driessen et al[28]	Netherlands; 4 large companies (railway transportation company, airline company, university, medical hospital, steel company).	3,047 workers; low back pain	RCT; 12 months	Individual and Organizational (Stay@Work participatory ergonomics program); Both groups watched 3 short (45 s) educative movies about LBP and NP prevention. Group A: interventional group (brainstormed about, evaluated and prioritized 3 top risk factors for LBP & NP and 3 top ergonomic measures, writing down in an implementation plan), Group B: control group.
	Greenwood et al [29]	West Virginia, US; Large Underground coal mining	278 workers; low back disability	RCT; 9 months	Individual (recovery management after health and psychological evaluation); Very early intervention with 2 groups. Group A: Experimental group [$n = 117$; recovery management after health and psychological evaluation using a risk for extended disability predictive factor scale (at least 8 days after injury)], Group B: Control group ($n = 161$).
	Herman et al[30*]	North America; Large warehouse company	70 workers; low back pain	RCT; 6 months	Individual (naturopathic care); Group A: intervention group ($n = 39$; naturopathic care visits: acupuncture, exercise and dietary advice, relaxation training, back care educational booklet), Group B: control group ($n = 31$; standardized physiotherapy advice, back care educational booklet).
	Mitchell et al[31]	Oklahoma, US; Defense (Air force Base)	1,316 warehouse workers; back injuries	Case–control; 6 years	Ergonomic intervention with training; Back belt use, back injury prevention training for all new hires, annual instruction period for proper lifting techniques. Group A: workers using a back belt; Group B: control group (workers who chose not to wear belts).
	Shi[32*]	California, US; 6 Government divisions	205 workers; back injuries	RCT; 12 months	Individual with ergonomic improvements; Group A: control group ($n = 4,398$ country employees), Group B: intervention group ($n = 205$; health risk assessment before and after the injury prevention program that included education, training, physical fitness activities, and ergonomic improvement).

(Continued on next page)

TABLE 1. (*Continued*)

		Country; Industrial Sector; Company size	Number of Participants; Target Problem	Type of Study Design; Measurement Time Period	Type and Description of the Intervention
	Speklé et al[33]	Netherlands; 7 companies	638 computer workers; neck and upper limb symptoms	RCT; 12 months	Individual (RSI QuickScan intervention); Group A: intervention group ($n = 320$; a set of 16 individual and group-level interventions, ie, individual workstation check, eyesight check, education program on the prevention of arm, shoulder, and neck symptoms, training on handling stress), Group B: usual care group ($n = 318$).
	Tuchin[34*]	Sydney, Australia; Large Postal service	121 workers; back injuries	RCT; 6 months	Individual (education program); Group A: control group ($n = 27$; no education, instructed to perform a series of daily exercises), Group B: intervention group ($n = 34$; spinal care lecture $\approx$ 120 min included an educational part of spinal anatomy, causes of back pain and injuries, as well as preventive and treatment activities), Group C: nonintervention group ($n = 60$).
	Versloot et al[35*]	Netherlands; Transportation (bus company)	500 workers; low back pain	RCT; 48 months	Individual (back school health education program); Group A: experimental group ($n = 200$; back school program consisted of 3 training sessions: first session included education and practice related to physical health; second and third sessions included workers' experiences of the last 6 months, summary of the first session), Group B: control group ($n = 300$).
Mental health	Geraedts et al[36]	Netherlands; 6 large companies (2 banking companies, 2 research institutes, 1 security company, 1 university)	231 workers; depressive symptoms	RCT; 12 months	Individual (brief Web-based intervention); Group A: intervention group ($n = 116$; Happy@Work intervention including problem solving treatment cognitive therapy and a guideline to prevent work-related stress; 6 weekly lessons (information about the theme, examples, assignments); participants start with a new lesson after feedback reception on their assignment from a coach), Group B: usual care ($n = 115$).
	Noben et al[37*]	Netherlands; Health care; Large	413 workers; mental health complaints	RCT; 6 months	Individual (occupational physician program; Group A: intervention group ($n = 207$; personalized feedback, referral to the occupational physician [3-hour training following a 7-step protocol)], Group B: control group (n = 206; screening without feedback, unrestricted access to usual care).

(Continued on next page)

TABLE 1. (*Continued*)

		Country; Industrial Sector; Company size	Number of Participants; Target Problem	Type of Study Design; Measurement Time Period	Type and Description of the Intervention
	Smoot and Gonzales[38*]	Atlanta, US; Health care; Large	72 workers; work-related stress	Controlled before and after; 12 months	Individual (communication skills training); Group A: control group ($n = 37$), Group B: intervention group ($n = 35$; a 32-hour interpersonal communications program, based on the Carkhuff model, in sequential 8-hour sessions held once a week for 4 weeks; Included didactic experiential component, cognitive component & accurate empathy).
Other health problems	Banco et al[39*]	Connecticut, US; Retail and trade (supermarket employees); Large company	199 workers; cutting injuries	RCT; 12 months	Organizational (Ergonomic intervention with education); 3 groups of similar stores. Group A stores: new safety cutters with training, Group B stores: old cutters with training, Group C stores: control group (old cutters without training).
	Engst et al[40*]	Canada; Health care	50 workers; risk injuries	Controlled before and after; 48 months	Organizational (ceiling lift program); Group A: intervention group (75-bed extended care unit with ceiling lifts, tracking directly into all of the washrooms, 1-hour session (education and training) by occupational therapist), Group B: control group (75-bed extended care unit without ceiling lifts).
	Orenstein et al[41]	Virginia; US; Health care	262 workers; Needlestick injuries	Controlled before and after; 12 months	Organizational (protective devices); Group A: control group, Group B: intervention group (6 months without the use of protective devices, 6 months extensive educational program to introduce protective devices).
	Hengel et al[42*]	Netherlands; Construction;	293 workers; health and work ability	RCT; 12 months	Individual; Group A: intervention group (two 30-min training sessions with a physical therapist, Rest-Break tool, two empowerment training sessions), Group B: control group (usual practice).
	van der Meer et al[43]	Netherlands; Health care	1,649 workers; hand eczema	RCT; 12 months	Individual (multifaceted implementation strategy); Group A: intervention group ($n = 876$; education on HE, participatory working groups, role models, reminders, leaflet), Group B: control group ($n = 773$; leaflet).
	Watson et al[44*]	UK; Local Authority Council	57 workers; substance abuse (alcohol)	RCT; 12 months	Individual (brief intervention one-to-one consultation by a registered nurse); Group A: intervention group ($n = 28$; incorporates Feedback, Responsibility, Advice, Menu of options, Empathy, Self-efficacy model), Group B: control group ($n = 29$).

*Cost-effective studies.

TABLE 2. Data Extraction by Targeted Health Problems: Economic Evaluation Characteristics of Included Studies

		Type and Description of Economic Analysis	Economic Evaluation Results	Cost Description	Economic Consequences; Description of Economic Consequences	Other Outcomes and Results; Outcomes and Results Description
Musculoskeletal disorders	Aboagye et al[26]	CUA (with Sensitivity Analysis); The Incremental cost-effectiveness ratio was estimated using mean incremental cost and the adjusted mean incremental QALY.	Medical yoga costs 206€ less than exercise therapy and 150€ more than self-care advice. The improvement in HRQL appeared to be better with medical yoga than with self-care advice (ICER: 4,984€/ QUALY) and equal for medical yoga and exercise therapy. Medical yoga can be cost-effective if an employer considers that the improvement in employee's HRQL can translate into productivity benefits.	Direct costs: physician assessment (medical yoga: 3,588€, exercise: 3,588€, advice: 3,795€), physician advice (1898€), yoga trainer (9568€), physiotherapists (19,061€), equipment (medical yoga: 120€, exercise: 1,316€, advice: 127€). Total direct costs: medical yoga (1,3276€), exercise (23,965€), advice (5,819€). Mean direct cost: medical yoga (255€), exercise (461€), advice (106€).	.	HRQL (improved significantly by medical yoga compared with self-care advice, but not more than by exercise therapy).
	Bernaards et al[27*]	CEA (with Sensitivity Analysis); Total costs were compared to the effects on recovery & pain intensity.	The total costs for WS were 451€ less than for the usual care, while for WSPA were 230€ more than usual care and 694€ more than WS. Neither intervention was cost-effective in improving overall recovery compared with usual care. WS intervention was cost-effective in reducing average pain compared with usual care (statistically significant results but has weak clinical effect and cannot, therefore be recommended). Company's willingness to pay: 900€/1-point reduction in average pain.	Direct and indirect costs; Intervention costs: counselors (12.5€/worker), time spent on group meetings (WS: 79.5€/ worker, WSPA: 109.5€/ worker), costs of elastic bands for WSPA group (3.2€/ worker), breaks and exercise reminder software (4.5€/ worker or 25€/ worker), Total intervention costs: WS (108€), WSPA (141€), usual care (16€), Costs of productivity loss: WS (1,799€), WSPA (2,670€), usual care (2,294€), Total costs: WS (1907€), WSPA (2,811€), usual care (2,310€).	The costs of productivity loss for WS were 543€ less than for usual care, while for WSPA were 104€ more than usual care and 661€ more than WP. The costs for sickness absence for WS were 583€ less than for usual care, while for WSPA were 51€ more than usual care and 648€ more than WP.	Neck/shoulder average pain reduction
	Driessen et al[28]	CEA and CBA (without Sensitivity Analysis); ICER was conducted using the four health outcomes.	Monetary loss of 78€/worker. The PE intervention program was neither cost-effective nor cost-beneficial.	Direct and indirect costs; Health care costs: visits to health care providers, diagnostic examinations, medication. PE intervention costs: 29€/worker (study protocol development, ergonomists' training costs, ergonomists' costs for guiding the working groups, costs of the total work time, costs of the 4-hour implementation training, costs for room rental, refreshments and training materials).	Mean total costs (health care costs, costs of productivity losses) in the intervention group were 127€ higher than those in the control group.	Low back pain, neck pain, work performance, sick leave (no statistically significant differences between groups).

(Continued on next page)

TABLE 2. (*Continued*)

	Type and Description of Economic Analysis	Economic Evaluation Results	Cost Description	Economic Consequences; Description of Economic Consequences	Other Outcomes and Results; Outcomes and Results Description
Greenwood et al[29]	CBA (without Sensitivity Analysis)	The overall costs of the intervention were $49,505. The very early intervention was as costly as the standard care and was not more effective.	Direct and indirect costs; Initial evaluation costs/ case including travel: $110. Mean cost for the recovery management services/ case: $651.38; Medical costs: $3,365 (intervention) and $2,965 (control); Disability costs: $5,568 (intervention) and $4,967(control).	Medical costs increased with the management intervention, while disability costs were not reduced.	Predictive factors of disability and medical benefits; locus of control, alcohol abuse & poor or unsafe environmental surroundings (statistically significant).
Herman et al[30*]	CEA (with Sensitivity Analysis); CEA was calculated in terms of cost/day of absenteeism reduced and ROI.	Naturopathic care is a cost-effective alternative to standardized physiotherapy education. ICER: $154/ absentee day avoided. ROI: 7.9%.	Direct and indirect costs; Study treatment costs: naturopathic care ($1,469), control ($337). Total adjunctive care costs (chiropractic visit costs, massage visit costs, physiotherapist visit costs, pain medication costs): naturopathic care (-$840), control ($363). Estimated productivity loss: naturopathic care (-$817), control ($324). Adjunctive costs paid by employer: naturopathic care ($17), control ($124).	Total adjunctive care savings: $1,203. Productivity loss savings: $1,141. Adjunctive costs paid by the employer (savings): $107	Absenteeism (reduction); treatment of chronic low back pain.
Mitchell et al[31]	CEA (without Sensitivity Analysis); CEA was performed on costs applicable to providing the belts, treatment of injury and lost or limited duty work days.	Back belts appear to be minimally effective in preventing injury, however they are not cost-effective. Costs of injury wearing a belt are substantially higher than if injured otherwise.	Direct and indirect costs; Costs of belts: $60,000 (intervention); Costs of treatment (medication, back belt, back school, roentgenograms, physical therapy, specialist referral): $18,910 (intervention) and $10,971 (control); Costs of lost days: $101,010 (intervention) and 138,320 (control); Costs of limited days: $215,880 (intervention) and $ 91,030 (control). Total costs: $395,800 (intervention) and $240,321 (control).	Total costs/injured worker (evaluation, treatment and referral uniformly): in the intervention group were $15,5479 higher than those in the control group; lost work days savings ($37,310); costs of limited days (-$124,850).	Rate of limited working days (increase), rate of lost time injury (decrease), rate of back injuries/1,000 workers (increase).
Shi[32*]	CBA (without Sensitivity Analysis)	The net benefit of back injury prevention program was $161,108; the return on investment (ROI) was 179%. The intervention was beneficial.	Direct costs: Payments to outside consultants and providers: $60,000, Materials for the program: $ 10,000, Wages: $20,000.	Medical claims savings: $113,348; sick day savings: $137,760; Total costs reduced: $251,108.	Back pain prevalence (modest decline), satisfaction (improved), risk reduction (improved).

(Continued on next page)

TABLE 2. (*Continued*)

	Type and Description of Economic Analysis	Economic Evaluation Results	Cost Description	Economic Consequences; Description of Economic Consequences	Other Outcomes and Results; Outcomes and Results Description
Speklé et al[33]	CEA and CBA (with Sensitivity Analysis); CEA used the total costs for the outcome's risk factors and prevalence.	The difference in total direct costs between the two groups: 30.73€. Monetary investments: 58.97€/ worker (intervention) & 28.24€/ worker (usual care). ICER/ point change in cost of sick leave: 0.39€. The intervention was not cost-effective compared to usual care.	Direct and indirect costs; Health care costs: general practitioner (21.03€/ visit), medical specialist (102.01€/ visit), physiotherapist and alternative therapist (23.68€/ visit), occupational physiotherapist (121.50€/hour), occupational psychologist (126.50€/ hour), occupational physician (70.00€/ 20 min). Purchased products for symptom reduction: 0–50€ range costs. Intervention costs: RSI Quick-Scan questionnaire (15.00€), information session (30.00€), training RSI & Stress (90.00€), consult occupational physician (70.00€/ 20 min), eyesight test (20.00€), individual workplace assessment (330.00€), task analyses (60.00€). Sick leave: 20.89€-49.78€ range costs/ hour.	Indirect costs due to sick leave (80.20€ higher in the intervention group).	Exposure to risk factors, the prevalence of arm, shoulder & neck symptoms, the number of days of sick leaves (increase).
Tuchin[34*]	CBA (without Sensitivity Analysis)	The implied net present value was $52,080. The saving could be in excess of $50,000 for a 3- month period (authors' comment). A short-term reduction of back injuries was reported. The intervention was cost-effective in reducing working days lost due to back pain or injury.	Direct & indirect costs; Total costs (training costs ($35/ worker) and worker time costs for training ($36/ worker)): $19,880; $71/worker.	Total absenteeism savings: $71,960; $257/worker due to absence expenses reduction.	Days lost from work & number of spinal injuries (reduced)
Versloot et al[35*]	CEA (without Sensitivity Analysis); The costs of the back school program were compared with the savings of the reduction in absenteeism.	The net present value was $103,400 (change in absenteeism was assessed in relation to the change in the control group). The net present value was $70,200 (change in absenteeism was assessed only within the intervention group). The back school program was cost-effective in relation to the reduction of costs of absenteeism.	Direct and indirect costs; Total costs of the intervention (costs of the total training program and wages due to lost working hours): $46,000; $230/ worker	Total absenteeism savings (based on changes between the intervention and control group): $149,400; $900/ worker. Total absenteeism savings (based on changes within the intervention group): $116,200; $700/ worker.	Sick leave, quality, and perceived effect of program; A reduction in mean length of absenteeism/worker: 6.5 days/ year (based on changes between the intervention and control group) and 5 days/year (based on changes within the intervention group).

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TABLE 2. (*Continued*)

		Type and Description of Economic Analysis	Economic Evaluation Results	Cost Description	Economic Consequences; Description of Economic Consequences	Other Outcomes and Results; Outcomes and Results Description
Mental health	Geraedts et al[36]	CEA and CUA (with Sensitivity Analysis); ICER was calculated for the depressive symptoms. CEACs: the probability of the intervention being cost-effective in comparison with usual care for a range of ceiling ratios. ROI.	ICER for depressive symptoms: 224, Probability gradually increases with increasing values of willingness to pay to a maximum of 0.95 at a ceiling ratio of 3,500€, ICER for clinically significant change: -4664, Probability gradually increases with increasing values of willingness to pay to a maximum of 0.95 at a ceiling ratio of 115,000€. Cost-savings: 382,354€/ every QALY lost. Total benefits (occupational health, absenteeism, presenteeism costs): 793€ (average), Net benefit: 508€ (average), BCR: 2.8, ROI: 178%. The intervention's probability of financial return: 0.63. Significant intervention effect on depressive symptoms. The intervention is not cost-saving to the employer.	Direct and indirect costs; Intervention costs (web site hosting, maintenance costs, labor costs of the coaches): 285€; Occupational health costs: 41€ (for intervention group) and 48€ (for control group); Absenteeism costs: 8,668€ (for interventional group) and 8,175€ (for control group); Presenteeism costs: 13,980€ (for intervention group) and 1,5259€ (for control group); Total: 22,974€ (for interventional group) and 2,3482€ (for control group).	Costs of Productivity losses: Absenteeism costs (mean cost difference between the two groups): 492€; Presenteeism costs (mean cost difference between the two groups): -1278.	Depressive symptoms (improved)
	Noben et al[37*]	CBA (with Sensitivity Analysis); ROI.	Net benefits: 651€/ worker. ROI: 11€/ 1€ investment. Beneficial intervention (limited time horizon).	Direct and indirect costs; Intervention costs (web-based screening and feedback module, periodically upgrading the module, hosting on a server: 4€/ worker; occupational physician consulting: 73€/ worker; occupational physician assistant: 3€/ worker; occupational physician training in using the protocol: 50€/ visit): 130€/ worker. Costs of productivity losses. Mean/ worker intervention costs: 89€ (intervention group) and 25€ (control group).	Cost difference between the two groups: 64€ (statistically significant). Cost reductions resulting from greater productivity: 715€ (statistically significant)	Mental health complaints (anxiety, distress, work-related fatigue, risky drinking, depression, & post-traumatic stress disorder), productivity (improved)

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TABLE 2. (*Continued*)

		Type and Description of Economic Analysis	Economic Evaluation Results	Cost Description	Economic Consequences; Description of Economic Consequences	Other Outcomes and Results; Outcomes and Results Description
	Smoot and Gonzales[38*]	CBA (without Sensitivity Analysis)	Substantial savings for the intervention group and increased expenditures for the control group. The training focusing on improving empathic communication skills is promising as a proactive, cost-effective approach to reducing staff turnover ($21,606) and improving both staff and patient outcomes.	Direct and indirect costs; Total cost for training staff: $13,145. For intervention group: Staff resignations and transfers: $35,358 (1990), $13,752 (1991); Sick leave: $26,490 (1990), $19,032 (1991); Annual leave: $35,142 (1990), $9,408 (1991); Patients' rights complaints: $3,690 (1990), $1,110 (1991); Incidents of restraint and seclusion: $17,280 (1990), $12,096 (1991); Assaults on staff: $276 (1990), $246 (1991); Total: $118,236 (1990), $55,644 (1991). For control group: Staff resignations and transfers: $25,536 (1990) and $29,466 (1991); Sick leave: $21,948 (1990) and $20,544 (1991); Annual leave: $25302 (1990) and $27,246 (1991); Patients' rights complaints: $738 (1990) & $2592 (1991); Incidents of restraint and seclusion: $16,416 (1990) & $32,832 (1991); Assaults on staff: $768 (1990) and $276 (1991); Total: $90,708 (1990) and $112,956 (1991).	Expenditures for intervention group were reduced by ≈$62,592. Expenditures for control group increased by $22,248.	Lower staff turnover (-61.1%), less sick (-28.2%) & annual leave (-73.2%), staff satisfaction (increased), fewer patients' rights complaints (-69.9%), fewer assaults on staff (-10.9%), less incidents of restraint & seclusion (-30%
Other health problems	Banco et al[39*]	CBA (without Sensitivity Analysis)	Total net savings for the Group A stores (new cutter and education) were $245 per 100,000 man hours/store and a total net savings of $29,413/ year for the chain. Benefits for the Group B stores (education) were: $106 per 100,000 man-hours/ store and for the chain was $12.773. Intervention A was more cost-effective.	Direct and indirect costs; Supply costs (case cutters): $0.17/ cutter for old cutters vs $2.35/ cutter for new safety cutters, $362 (group A), $269 (group B), and $403 (group C); Education costs: $20/ =hour health educators, $333 (group A) and $362 (group B); Compensation savings (medical care and workers' compensation): $317 (group A) and $188 (group B); Time lost savings: $107 (group A) and $98 (group B).	Wage value of time loss from work due to injury, employees' compensation expenses (medical care and indemnity).	Injury rates/100,000 man hours; reduction of cutting injuries, reduction of other types of injuries.

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TABLE 2. (*Continued*)

	Type and Description of Economic Analysis	Economic Evaluation Results	Cost Description	Economic Consequences; Description of Economic Consequences	Other Outcomes and Results; Outcomes and Results Description
Engst et al[40*]	CBA (without Sensitivity Analysis)	Payback period for the intervention: 9.6 years (including all resident handling claims) and 6.5 years (including only lifting and transferring claims). Ceiling lifts were effective method only for lifting and transferring residents.	Direct and indirect costs; Total intervention costs: $284,297. Medical costs, lost work time costs, purchasing and installing the intervention, hiring a program coordinator, staff replacement costs for education, and training.	Adjusted direct savings: $9,835 (all resident handling) and $14,493 (lifting and transferring tasks). Compensation Claims for the intervention group: 22.7% decrease (resident handling), 68.3% decrease (lifting and transferring), and 52.5% increase (repositioning). Compensation Claims for the control group: 12.2% decrease (resident handling), 68.3% increase (lifting & transferring) and 33.9% decrease (repositioning).	Risk for musculoskeletal injuries (decrease), job satisfaction (increase for both groups), physical discomfort, staff perceptions, and preferences.
Orenstein, et al.,[41] (1995)	CEA (with Sensitivity Analysis)	The average evaluation cost/ NSI: $260. Total NSI evaluation cost: $8,580 (before intervention) and $3,649 (after intervention). Cost per NSI prevented: $789. The use of protective devices was not beneficial.	Direct costs of NSI: cost of employee time, laboratory technician time, testing fees. Total device costs: $2,444 [before intervention (needles, heparin locks, 3 ml syringes)] and $22,558 [after intervention (protective devices, needles, syringes)]. Total costs: $11,024 (before intervention) and $ 26,198 (after intervention).	Total NSI cost savings: $4,940. Excess cost: $15,178.	Number of needle-stick injuries decreased (not statistically significant).
Hengel et al[42*]	CEA and CBA (with Sensitivity Analysis); CEA was calculated for the three health outcomes; Benefit cost ratio: by dividing the benefits by the costs. ROI.	ICER for work ability: 5,243€, ICERs for physical health: 798, ICERs for mental health: -642, ICERs for upper extremities: 12,133, ICERs for lower extremities: 59,716. Net benefit: 641€. Benefit cost ratio: 6.4 (for each 1€ invested, 6.4€/ worker was gained). ROI: 544%. The intervention was cost-effective only for absenteeism reduction (and cannot therefore be recommended).	Direct and indirect costs; Mean intervention costs (physician therapist, empowerment trainer, material costs): 118€/ worker. Costs of productivity losses.	Costs of productivity losses from absenteeism and presenteeism; Savings in sickness absenteeism costs: 760€/ worker.	

(*Continued on next page*)

TABLE 2. (*Continued*)

	Type and Description of Economic Analysis	Economic Evaluation Results	Cost Description	Economic Consequences; Description of Economic Consequences	Other Outcomes and Results; Outcomes and Results Description
van der Meer et al[43]	CEA (with Sensitivity Analysis); CEACs: the probability of the intervention being cost-effective in comparison with usual care for a range of ceiling ratios. ROI.	ICER for HE: -57,299, CEAC: 0.09, Probability gradually increases with increasing values of willingness to pay to a maximum of 0.84 at a ceiling ratio of 580,000€, ICER for compliance measure: 15,559, CEAC: 0.09, Probability gradually increases with increasing values of willingness to pay to a maximum of 0.82 at a ceiling ratio of 480,000€. ROI was negative during the following up. The intervention's probability of financial return is: 0.12. The intervention was neither cost-effective nor cost-beneficial to the employer.	Direct & indirect costs; Intervention costs: 114€/ worker. Primary and secondary health care services costs, costs of absenteeism, costs of presenteeism. Total savings: 3,318€.	Costs of productivity losses due to HE. Presenteeism costs (the difference between the two groups): 2,764€.	Prevalence of hand eczema.
Watson et al[44*]	CUA (without Sensitivity Analysis)	The difference between two groups: -0.002 - (-0.010). Net advantage of the intervention: 0.008 QALYs. Net saving (the difference in service costs between two groups): £344.5/person. The alcohol brief intervention appears to be cost-effective.	Direct costs; Costs of the intervention: £12.48/26 min or £0.48/min. No analytical costs were presented.	.	Maximum number of units in 1 day, number of drinking days/week, total weekly consumption, AUDIT scores, general health.

*Cost-effective studies.

TABLE 3. Risk of Bias in Included Studies: Low Risk (+); Unclear Risk (?); High Risk (-); Not Applicable N/A

		Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	Other Bias	Summary Assessments
Musculoskeletal disorders	Aboagye et al[26]	(+)	(?)	(?)	(+)	(?)	(+)	(?)	Unclear risk of bias
	Bernaards et al [27*]	(+)	(+)	(+)	(+)	(+)	(+)	(+)	Low risk of bias
	Driessen et al[28]	(+)	(+)	(+)	(+)	(+)	(+)	(+)	Low risk of bias
	Greenwood et al[29]	(+)	(+)	(?)	(?)	(?)	(+)	(?)	Unclear risk of bias
	Herman et al[30*]	(+)	(?)	(+)	(+)	(+)	(+)	(+)	Unclear risk of bias
	Mitchell et al [31]	N/A	N/A	N/A	(?)	(?)	(+)	(?)	Unclear risk of bias
	Shi[32*]	(?)	(?)	(+)	(+)	(?)	(?)	(?)	Unclear risk of bias
	Speklé et al[33]	(+)	(+)	(+)	(+)	(?)	(+)	(+)	Unclear risk of bias
	Tuchin[34*]	(?)	(-)	(?)	(+)	(?)	(+)	(?)	High risk of bias
	Versloot et al[35*]	(?)	(?)	(+)	(+)	(?)	(+)	(-)	High risk of bias
Mental health	Geraedts et al[36]	(+)	(+)	(+)	(+)	(+)	(+)	(+)	Low risk of bias
	Noben et al [37*]	(+)	(+)	(+)	(+)	(+)	(+)	(+)	Low risk of bias
	Smoot and Gonzales[38*]	N/A	N/A	(-)	(+)	(?)	(?)	(?)	High risk of bias
Other health problems	Banco et al[39*]	(?)	(?)	(+)	(+)	(?)	(+)	(?)	Unclear risk of bias
	Engst et al[40*]	N/A	N/A	(+)	(+)	(?)	(+)	(+)	Unclear risk of bias
	Orenstein, et al [41]	N/A	N/A	(+)	(+)	(?)	(+)	(+)	Unclear risk of bias
	Hengel et al[42*]	(+)	(+)	(+)	(+)	(+)	(+)	(+)	Low risk of bias
	van der Meer et al [43]	(+)	(+)	(+)	(+)	(+)	(+)	(+)	Low risk of bias
	Watson et al[44*]	(+)	(+)	(+)	(+)	(+)	(+)	(+)	Low risk of bias

*Cost-effective studies.

Two studies conducted both CEA and CBA,[28,33] while three conducted a CEA,[31] a CBA,[29] or a CUA.[26] The studies identified both the direct and the indirect costs of the interventions, except for Aboagye et al[26] who did not include indirect costs.

In the group of mental health interventions, the intervention of the study carried out by Geraedts et al[36] was not cost beneficial. The intervention study achieved a high score on the CHEC-list and had a low risk of bias. The study conducted both CEA and CUA and included both direct and indirect costs.

In the group of other preventive interventions, two studies,[41,43] which conducted a CEA, were not shown to be cost-effective. van der Meer et al[43] achieved a high score on the CHEC-list and had low risk of bias, while Orenstein et al[41] achieved a moderate score on the CHEC-list and had unclear risk of bias. Orenstein et al[41] did not include indirect costs, which is essential information in order to be able to draw unambiguous conclusions about the cost-effectiveness of an intervention.

DISCUSSION

Main Findings

The main aim of this systematic review was to evaluate the cost-effectiveness of OSH interventions from the employer perspective. The small number of published studies, the variety of OSH-interventions, the targeted health problems, and outcomes in combination with shifting quality make it difficult to draw conclusions about the cost-effectiveness of specific OSH-interventions. This heterogeneity was also the reason why we did not apply meta-analytical approach to the data. Nevertheless, the single studies do give some interesting results.

Nineteen individual-level and organizational-level intervention studies, divided into three groups (MSD, mental health, and other preventive interventions), fulfilled the inclusion criteria and were included in the study. MSD and mental health disorders are the two most common causes of sickness absence and high costs for employers.[45,46] Both these conditions have previously been shown to be related to the work environment.[46–48] Only one of the MSD studies looked at an organizational-level intervention, while another looked at both organizational and individual levels. None of these interventions were shown to be cost-effective. Of the mental health intervention studies, none included organizational-level changes, which indicates inadequate interest in interventions at this level. As mental health problems can arise as a result of work environment problems, there is a need of OSH interventions targeting the organizational level to prevent these problems. According to several studies, organizational-level changes to improve psychosocial working conditions can have important and beneficial effects on health.[49,50] However, difficulties in evaluating the effectiveness of such interventions can affect employers in their decision to conduct them.[51] As economic incentives are important for several employers in order to motivate them to engage in OSH interventions, studies evaluating cost-effectiveness of organizational-level interventions are needed. In the group of ''other preventive interventions,'' two cost-effective organizational-level interventions[39,40] and one which was not shown to be cost-effective[41] were related to injuries (cutting injuries, MSD injuries, needle-stick injuries). Although the workplace is a setting venue that provides access to employees with work-related health problems, companies do not appear to take advantage of this for their benefit by implementing organizational-level interventions. They tend rather to focus on interventions at individual-level. It is unclear whether this is due to company preference or because researchers tend to conduct mostly individual-level interventions.

The main type of economic analysis of the interventions was the CBA, which is highly appropriate for OSH studies. However, CEA and CUA are also useful in OSH if the outcome of interest can be measured in natural units.[52] Several studies were excluded from the review during the eligibility process because they lacked a control group. The control group is an essential element of a full economic evaluation; lack of control group blurs the distinction between the effects of an intervention and autonomous change over time. Conducting a full economic evaluation, which is the only type of economic analysis that provides valid information about efficiency,[20,25] requires the identification, measurement, and valuation of costs and consequences because it compares the effectiveness and the benefits of two or more interventions. If one wants to be able to

TABLE 4. Internal and External Validity of Included Studies; The Consensus Health Economic Criteria List: Yes = 1; No = 0

	Musculoskeletal Disorders										Mental Health			Other Health Problems					
	Aboagye et al[26]	Bernaards et al[27*]	Driessen et al[28]	Greenwood et al[29]	Herman et al[30*]	Mitchell et al[31]	Shi[32*]	Speklé et al[33]	Tuchin[34*]	Versloot et al[35*]	Geraedts et al[36]	Noben et al[37*]	Smoot and Gonzales[38*]	Banco et al[39*]	Engst et al[40*]	Orenstein, et al[41]	Hengel, et al[42*]	van der Meer et al,[43]	Watson, et al[44*]
Is the study population clearly described?	1	1	1	1	1	0	1	1	0	0	1	1	1	0	0	0	1	1	1
Are competing alternatives clearly described?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Is a well-defined research question posed in answerable form?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Is the economic study design appropriate to the stated objective?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Is the chosen time horizon appropriate in order to include relevant costs and consequences?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Is the actual perspective chosen appropriate?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Are all important and relevant costs for each alternative identified?	0	1	1	0	1	1	0	1	1	0	1	1	1	1	0	1	1	1	0
Are all costs measured appropriately in physical units?	1	1	1	0	1	0	0	1	0	0	1	1	0	0	0	1	1	1	0
Are costs valued appropriately?	1	1	1	0	1	0	0	1	0	0	1	1	0	0	0	0	1	1	0
Are all important and relevant outcomes for each alternative identified?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Are all outcomes measured appropriately?	1	1	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	1	1
Are outcomes valued appropriately?	1	1	1	0	1	0	0	1	1	0	1	1	1	0	1	1	1	1	1
Is an incremental analysis of costs and outcomes of alternatives performed?	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
Are all future costs and outcomes discounted appropriately?	1	1	1	1	1	0	1	1	1	0	1	1	1	1	0	1	1	1	1
Are all important variables, whose values are uncertain, appropriately subjected to sensitivity analysis?	1	1	0	0	1	0	0	1	0	0	1	1	0	0	0	1	1	1	0
Do the conclusions follow from the data reported?	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
Does the study discuss the generalizability of the results to other settings and patient/client groups?	1	1	1	0	0	0	0	1	0	0	1	1	0	0	0	0	1	0	0
Does the article indicate that there is no potential conflict of interest of study researcher(s) and funder(s)?	1	1	1	0	1	0	0	0	0	0	1	1	0	1	1	0	1	1	1
Are ethical and distributional issues discussed appropriately?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total score (%)	17 (89)	18 (95)	17 (89)	9 (47)	17 (89)	9 (47)	11 (58)	17 (89)	11 (58)	8 (42)	18 (95)	18 (95)	12 (63)	11 (58)	11 (58)	14 (74)	18 (95)	17 (89)	13 (68)

*Cost-effective studies.

TABLE 5. A Summary of the Methodological Quality of Cost-Effective Interventions

	High Score on the CHEC-List With Low Risk of Bias	High Score on the CHEC-List With Unclear Risk of Bias	Moderate Score on the CHEC-List With Low Risk of Bias	Moderate Score on the CHEC-List With Unclear Risk of Bias	Moderate Score on the CHEC-List With High Risk of Bias	Low Score on the CHEC-List With High Risk of Bias
Musculoskeletal disorders	Bernaards et al[27] Intervention: work style Outcomes: neck/shoulder pain reduction (significant but small effect)	Herman et al[30] Intervention: naturopathic care Outcomes: absenteeism reduction; treatment of chronic low back pain	.	Shi[32] Intervention: back injury program Outcomes: back pain prevalence; back injury risk reduction	Tuchin[34] Intervention: spinal care lecture Outcomes: reduction of spinal injuries and back pain	Versloot et al[35] Intervention: back school program Outcomes: mean length of absenteeism
Mental health	Noben et al[37] Intervention: occupational physician consultation Outcomes: reduction of mental health complaints; production improvement	.	.	.	Smoot and Gonzales[38] Intervention: communication skills training program Outcomes: reduction of staff stress and turnover	.
Other health problems	Hengel et al[42] Intervention: physical therapist training session Outcomes: reduction in days of sick leave	.	Watson et al[44] Intervention: alcohol brief intervention Outcomes: reduction of alcohol-related harm	Banco et al[39] Intervention: new safety cutters Outcomes: reduction of cutting injuries	.	.
	.	.	.	Engst et al[40] Intervention: ceiling lifts Outcomes: reduction of risk of injuries and physical discomfort	.	.

draw conclusions about the cost-effectiveness of OSH, only the results of full economic evaluations (such as benefit–cost ratio, net benefits or savings, incremental cost-effectiveness ratio, cost per quality-adjusted life-year) should be used. Some economic studies that claim to be full economic evaluations may in fact only be partial evaluations.[53] For instance, an intervention can appear to be cost-effective but when compared with a control group it proves not to be.[18] This is a problem when evaluating the cost-effectiveness of OSH interventions. Moreover, small-medium enterprises (SMEs) are a neglected sector in OSH research and practice and there is a lack of economic evaluations of OSH interventions in this type of company, despite the fact that they dominate in most economies. SMEs need special attention because their knowledge of and financial resources for conducting interventions are limited. It is also difficult for SMEs to implement and adopt the strategies employed by larger organizations.[3,54,55]

Eight of the studies included in this review were published during the 1990s, most of them related to MSDs. Only two studies were published during the next decade, while there was a substantial increase in relevant published studies from 2010 onwards. Our findings indicate that older studies (pre-2005) scored poorly on the aspects of the assessment due to the insufficient information, while newer studies were rated as having high-quality evidence. However, further improvements in line with the CHEC-list are still needed, for example, the sensitivity analysis, the discussion of the generalizability of the results, and that of ethical and distributional issues.[24,52] In common with previous systematic reviews[2,6–8,19,20,56] that evaluated the cost-effectiveness of workplace interventions, the present review concludes that there is a need for further research and methodological quality improvements because of insufficient and poor results. High-quality evidence is also related to indirect costs, such as productivity losses, being sufficiently reported. Some economic evaluations, for example, may not present incremental cost-effectiveness and/or resource use (such as intervention staff hours, materials used, depreciation, overhead activities, traveling), or they may not include a full identification of all important and relevant costs (for instance indirect costs such as productivity loss, absenteeism, presenteeism). The costs may not have been measured appropriately, using a valid instrument, or they may not include any type of sensitivity analysis to assess the robustness of results.[2,19,20] The lack of this economic information makes it difficult to draw robust conclusions. In particular, the interventions of Aboagye et al[26] and Orenstein et al[41] might have been identified as non-cost-effective due to the lack of productivity losses costs.

In all, 11 interventions were evaluated as being cost-effective. Only three of them, one from each group, were rated as having high methodological quality with regard to undertaking and reporting economic evaluations and a low risk of bias. These were the following: MSD: work style[27]; mental health: occupational physician consultation[37]; other preventive interventions: physical therapist training session.[42] None of them, however, is recommended without reservation in its current form. According to Bernaards et al,[27] the observed pain reductions in the work style intervention group compared with usual care were significant but less than 30% and therefore not clinically relevant. Noben et al[37] recommended a wider implementation of the intervention because the period was too short to be able to judge whether the effects will be maintained over time. According to Hengel et al,[42] the intervention was cost-saving in terms of reduced sickness absenteeism costs, but not in terms of primary and secondary health outcomes. The generalizability and comparability of the studies of cost-effectiveness are debatable because of methodological differences and heterogeneous characteristics and effect measures, which make the evidence ambiguous. Even in the MSD group, where the health outcomes were similar (back pain and back injuries), the studies used a variety of interventions, with education as the only common factor. In addition, uncertainty surrounding unit cost estimates does not appear to have been considered within the analyses. As a result, the amount of economic evidence was very limited. The results should therefore be viewed with caution and regarded as preliminary. Nevertheless, the studies of Herman et al[30] and Watson et al[44] appear promising, given their methodological quality and sufficient degree of economic evidence. They also include features that encourage further research.

Strengths and Limitations

One of the strengths of this systematic review is the comprehensive search strategy used, which facilitated a more evidence-based approach to literature searching. Another important strength is the use of two methodological quality assessment tools, both recommended by Cochrane Collaboration, to assess simultaneously the risk of bias and the economic quality of the included studies. In the present systematic review, we did not include ''grey'' literature, which may have excluded some studies from the review. In addition, due to the heterogeneity of study designs, populations, interventions, and outcomes, we were unable to conduct a meta-analysis.

Conclusion and Implications for Future Research

Information about the financial benefits of OSH interventions is important for employers. The results of the present systematic review do not enable us to draw conclusions about specific interventions due to the limited number of economic evaluations, the diverse nature of the interventions, the number of targeted health problems and health outcomes, and the insufficient reporting of economic quality and risk of bias. Thus, our review highlights the need for more well-designed studies that address the economic merits of OSH interventions from the employer perspective and target diverse health problems, such as mental health, cardiovascular diseases, respiratory diseases, substance abuse, dangerous substances, and outcomes. Nevertheless, five of the cost-effective intervention studies can be considered promising, under certain conditions and modifications.[27,30,37,42,44]

An economic evaluation should serve to measure productivity, health, and safety, motivating the firms' principles to improve each of these methods of measurement, rather than just presenting a cost–benefit analysis of an intervention.[3] Although economic evaluation studies have been improved over the years, there is still room for further improvements. Although CBA is highly appropriate for OSH studies, CEA and CUA are also useful in OSH if the outcome of interest can be measured in natural units. We would also encourage the authors of economic evaluations to adopt more ambitious analytical strategies with more advanced regression techniques (see for instance the net benefit regression framework, recommended by Hoch and Dewa).[57] A full identification of all important and relevant costs should be given in relation to the perspective and the research question. The costs should be measured appropriately in physical units, using valid instruments. The sources of valuation should be clearly stated, the main cost should not be calculated using tariffs, and the discounting should be done appropriately. The outcomes should also be measured appropriately, using valid instruments, while the valuation method should be clearly stated. In addition, all important variables should be subjected to an appropriate sensitivity analysis.[1,5,24,58] Finally, further much-needed improvements are the inclusion of control groups and the development of intervention studies at organizational level.

The above findings are of value to employers, OSH practitioners, and policymakers who are interested in knowing what interventions are worth undertaking from a financial point of view.[2,7] Economic evaluations provide a unique opportunity to estimate the resource implications of OSH interventions at low

incremental cost. However, when interpreting economic evaluations of OSH interventions, it is important to consider that their results may not be directly applicable to other countries due to differences in health care and social security systems or other relevant factors. Nonetheless, economic evaluation results can be generalized from one country to another, after necessary calculations. Employers and stakeholders can exploit the extensive description of the interventions, the detailed list of resource use as well as information of the health care system and the allocation of costs.[5]

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